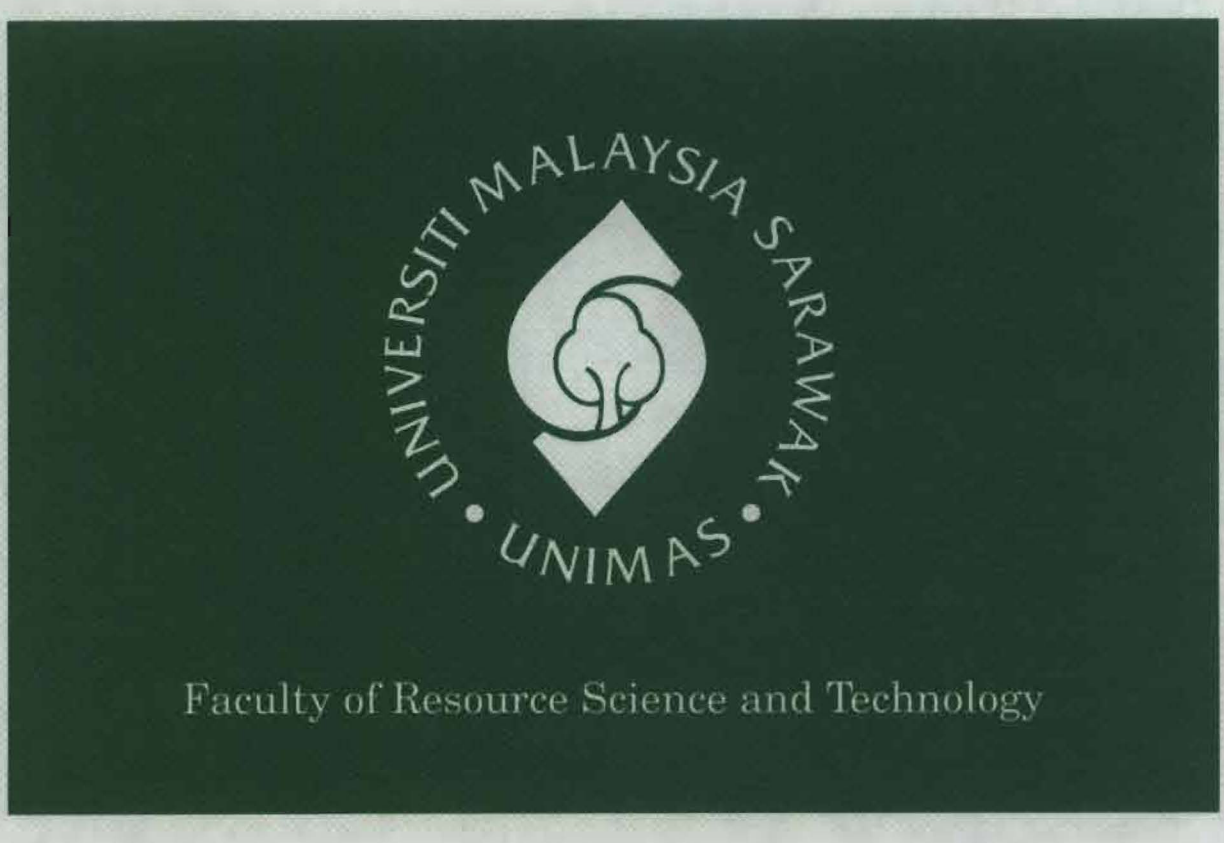

DIETARY RESOURCE PARTITIONING IN ANURAN LARVAE IN FORESTED AND OPEN AREAS IN UNIMAS CAMPUS, SARAWAK

Siti Zubaidah Ismail

Bachelor of Science with Honours
(Animal Resource Science and Management)
2007

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Animal Resource Science and Management Programme

Department of Zoology

Faculty of Resources Science and Technology

Universiti Malaysia Sarawak

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DECLARATION

No portion of the work referred to this dissertation has been submitted in support of an application for another degree of qualification of this or any other university or institution of higher learning.

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Dietary Resource Partitioning in Anuran Larvae in Forested and Open Areas in Unimas Campus, Sarawak

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ABSTRACT

A study on dietary resource partitioning in anuran larvae was conducted at Unimas Campus, Sarawak between August, 2006 to February, 2007. The diets of tadpoles of seven anuran species were examined to determine whether dietary resource partitioning occurs and whether the degree of dietary similarity is related to taxonomic affinity. A second objective was to determine whether tadpoles of each species consume different food types in different microhabitat types. Three species from an open waterway and four species from a forested area, representing two families (Ranidae and Rhacophoridae) were studied. Microalgae is the most dominant dietary component in intestinal samples of all tadpoles from both habitat categories. Dietary resource partitioning was found to be an important factor influencing the types of prey consumed by tadpoles, allowing the coexistence of closely-related species.

Key words: Diet, resource partitioning, anurans larvae, forest, open waterways.

ABSTRAK

Satu kajian mengenai pembahagian sumber diet dalam berudu telah dijalankan di Kampus Unimas, Sarawak di antara Ogos, 2006 hingga Februari, 2007. Diet daripada tujuh spesies berudu telah dikaji untuk mengetahui sama ada pembahagian sumber diet wujud dan terdapat kadar hubungan rapat dengan persamaan makanan terhadap taksonomi. Objektif kedua ialah untuk menentukan sama ada komposisi makanan bagi setiap spesies terhadap perbezaan makanan dari mikrohabitat yang berbeza wujud. Berudu yang terdiri daripada tiga spesies dari kawasan terbuka dan empat spesies dari kawasan hutan dari dua famili (Ranidae dan Rhacophoridae) telah dikaji. Mikroalgae adalah komponen tertinggi di dalam diet bagi semua spesies berudu di kedua-dua kategori habitat. Kajian menunjukkan pembahagian sumber diet mempengaruhi jenis makanan atau mangsa untuk di makan oleh berudu yang membolehkan spesies yang mempunyai pertalian rapat wujud bersama.

***Kata kunci**: Diet, pembahagian sumber, berudu, kawasan hutan, kawasan air terbuka.*

1.0 Introduction

Anurans consist of frogs and toads and there are 5,423 species of anurans recorded worldwide (Anon, 2007). A total of 186 species of amphibians have been recorded in Malaysia (Inger and Stuebing, 1997; Das and Haas, 2003). Forty years ago, only 96 species were known in Borneo; the current number species is 155 species of which 94 species are endemic to this island (Inger and Stuebing, 1999).

The larval stage of an anuran amphibian is referred to as a tadpole, and shows a great morphological diversity (Altig *et al.*, 2007). There are two ecological types in terms of gross morphology- the pond type and stream type: pond type tadpoles have deeper body and higher tail fins than do stream-type tadpoles (Zug *et al.*, 2005). Although tadpoles typically are in specific aquatic habitats for longer periods than their adults, they sometimes are more difficult to find and nearly always more difficult to identify (Altig *et al.*, 1998). According to Sampson (1978), the metamorphosis of the Anura is more complex compared to the other lineages within amphibians, and the anuran larvae have little in common with their much larger, better known adults.

Amphibians are an important energy transfer link between invertebrates and vertebrates (Dutra and Callisto, 2005). The natural diet of common frogs and their larvae is a topic that has received little attention (Altig *et al.*, 2007; Dutra and Callisto, 2005). Diet is especially important in tadpoles because many species are in short-lived aquatic environments. These areas further constrain for these tadpoles to consume foods that will ensure they achieve metamorphosis earlier to the drying of the area. A number of studies have addressed the question of feeding strategies in tadpoles,

conducted under controlled conditions or in the laboratory, but only a few have examined the natural diet of these organisms (Quammen and Durtsche, 2001).

At the end of larval stages, morphological transformation takes place, the result of the environment and external factors such as light, salinity, temperature and food supply (Shi, 1999). The adult is short-bodied and usually tailless, while the larva possesses a tail that is usually well-developed. According to Alford (1999), most tadpoles are primarily herbivores.

In this study, tadpoles were collected at the East Unimas campus from selected sites which were within peat swamp forests and from open areas such as drains, roadside puddles, construction areas, and puddles. Unimas campus is a suitable site to study dietary habits of tadpoles as previous studies have shown the existence of 15 species of frogs: *Leptobrachium nigrops, L. hendricksonii, Limnonectes ingeri, L. malesianus, L. paramacrodon, Bufo quadriporcatus, Rana baramica, R. glandulosa, Occidozyga laevis, Polypedates colletti, P. otilophus Rhacophorus appendiculatus, Pelophryne signata, Nyctixalus pictus* and *Rhacophorus pardalis*. In the open waterway areas, five species were recorded: *Fejervarya cancrivora, Bufo melanostictus, F. limnocharis, R. erythraea* and *P. leucomystax* (Ramlah, 2006; Omar, 2006).

The importance of resource use in association of tadpole communities is still unclear (Dutra and Callisto, 2005). Understanding the diet and natural history of these organisms are important to better understand their complex life histories, besides population fluctuations and the impact of habitat modification on those populations (Anderson *et al.*, 1999).

The study of tadpole diets and foraging behavior can reveal links to metamorphosis (Kupferberg, 1997). Information on the tadpoles of Borneo is scant compared to adult amphibians (Inger, 1986). According to Sinha *et al.* (2001), information of the food of tadpoles of various species can be used in rearing the species with medicinal values under laboratory conditions.

From this study, seven species from two families were found in the open and forested areas. The diet of tadpoles from these species was determined to find out if dietary resource partitioning occurs and whether the degree of dietary similarity is related to taxonomic affinity. Additionally, to identify the prey types ingested and compare the prey diversity of each tadpole species in forested and open areas.

1.1 Hypotheses

This project had two hypotheses:

First hypothesis

H_O: There are no significant differences between food resources of co-occurring species.

H_A: There are significant differences between food resources of co-occurring species.

Second hypothesis

H_O: There are no significant differences in the dietary diversity of tadpoles in forested and open areas.

H_A: There are significant differences in the dietary diversity of tadpoles in forested and open areas.

2.0 Literature review

A larval stage is the primitive state for anurans and their morphological diversity is immense. The tadpoles of frogs and toads have rounded bodies the gills are visible externally, except in the early stages of development and their hindlegs develop before forelegs (Arnold *et al.*, 1992). The external morphological characters of a tadpole that are useful in its identification include nares, eyes, spiracle, vent tube, tail shape, oral disc, and pigmentation. A majority of tadpole of anuran species has complex mouth parts.

In the larvae of most anuran species, the jaws comprise keratinized beaks overlying the infrarostral cartilages. The beak serves to cut large food into smaller pieces, and the oral apparatus requires a filter straining mechanism to capture food or items direct to the gut (Zug, 1993). It should be noted that independent feeding commences from Stages 25-26 because the formation of the oral disc (Gosner, 1960).

Feeding types of tadpoles can be categorised as obligate benthic (Ranidae), midwater suspension (Rhacophoridae and Microhylidae), macrophogus (Megophyridae), surface film (Megophyridae and Microhylidae) and bottom suspension feeders (Ranidae and Bufonidae) (Duellman and Trueb, 1985; Inger, 1986). According to Inger (1986), the five modes of the Bornean anuran larvae are related to differences in microhabitat distribution and diet composition. Most tadpoles are primarily herbivorous (Alford, 1999). According to Dutra and Callisto (2005), anuran larvae are mostly phytophagous, changing their food habitats and morphology at metamorphosis to adapt a more terrestrial body and mainly insectivorous diet.

According to Wassersug (1980), the internal morphology can be used to infer feeding strategies. Tadpoles may also occur at relatively high densities in streams, and be important primary consumers in these habitats (Clinnick, 1985, Flecker *et al.*, 1999 and Lamberti *et al.*, 1992).

The diet of tadpoles is diverse and varies widely across types of species and their environment (Huang *et al.*, 2003). Although some species had exclusive items in their diet, most tadpole species ingested the same items, but differed in the amount of each item consumed (Rossa-Feres *et al.*, 2004). Studies conducted by Inger (1986), found that the primary ingested food of Borneon tadpoles were algae, diatoms, fungi, ciliates, euglenoids, amoebae, miscellaneous protists, tracheoid plant fragments, rotifers, insects and crustaceans.

According to Kupferberg (1997), the diets of tadpoles may contain plants, animal tissues, algae, cyanobacteria, protozoans, other tadpoles, anuran eggs, various kinds of small animals, pollens and dissolved organic matter. The presence of plants in their diet showed that vegetation is used not only as a reproductive site, but also as foraging area. In general, the diversity of food groups increased or reduced in both season either wet season or dry season (Santos *et al.*, 2004).

The changes in the morphology in tadpoles are also influenced by its food supply and diet (Shi, 1999). According to a study by Tinggom (2005), the diet composition and resource partitioning of tadpoles are influenced by the feeding strategies, mouthparts, stages of organism and their habitat types. This study reported three species of tadpoles at the open area: *B. melanostictus, F. limnocharis* and *F. cancrivora.* These species did not feed on similar food types although they were

syntopic. According to Gillespie (2002), tadpole growth and development were not significantly affected by food type, but there was a trend toward increased performance on periphyton substrata. Study by Rossa-Feres *et al.* (2004), showed food partitioning is a major factor for the ecological separation of tadpole, which inhabited the same microhabitat.

According to Rossa-Feres *et al.* (2004), the importance of food partitioning in the organization of tadpole communities is questionable. From the study done by Heyer (1976), it was concluded that food plays no important role in habitat partitioning among species, whereas Inger (1986) showed that division of food was interlinked with distribution in space. There is little consensus regarding the occurrence of food partitioning and its role in the organization of tadpole communities (Rossa-Feres *et al.*, 2004). They suggested the ingestion of different proportions of the food items available in the habitat rather than in different diet compositions.

A study by Quammen and Durtsche (2001), found that three species of tadpoles from three different families are largely detritivores and most likely feed off periphyton from aquatic vegetation or immersed substrates. In their study, they also found that some tadpoles depend on carnivory of other tadpole species to achieve their metamorphic state. Dutra and Callisto (2005) found that algae and detritus were the most abundant types of food ingested. The large number of unidentified macroinvertebrates fragments, larvae and exuviae of chironomids and mayflies were also found. The macroinvertebrates as a supplement in their diets was believed to be transported by water current. According to Mokany and Shine (2003), diet of tadpole and mosquito larvae overlap significantly, potentially leading to competition for food. In their study, the mosquito larvae reduced the growth rates of tadpoles and tadpoles reduced the growth rates and survival of mosquito larvae.

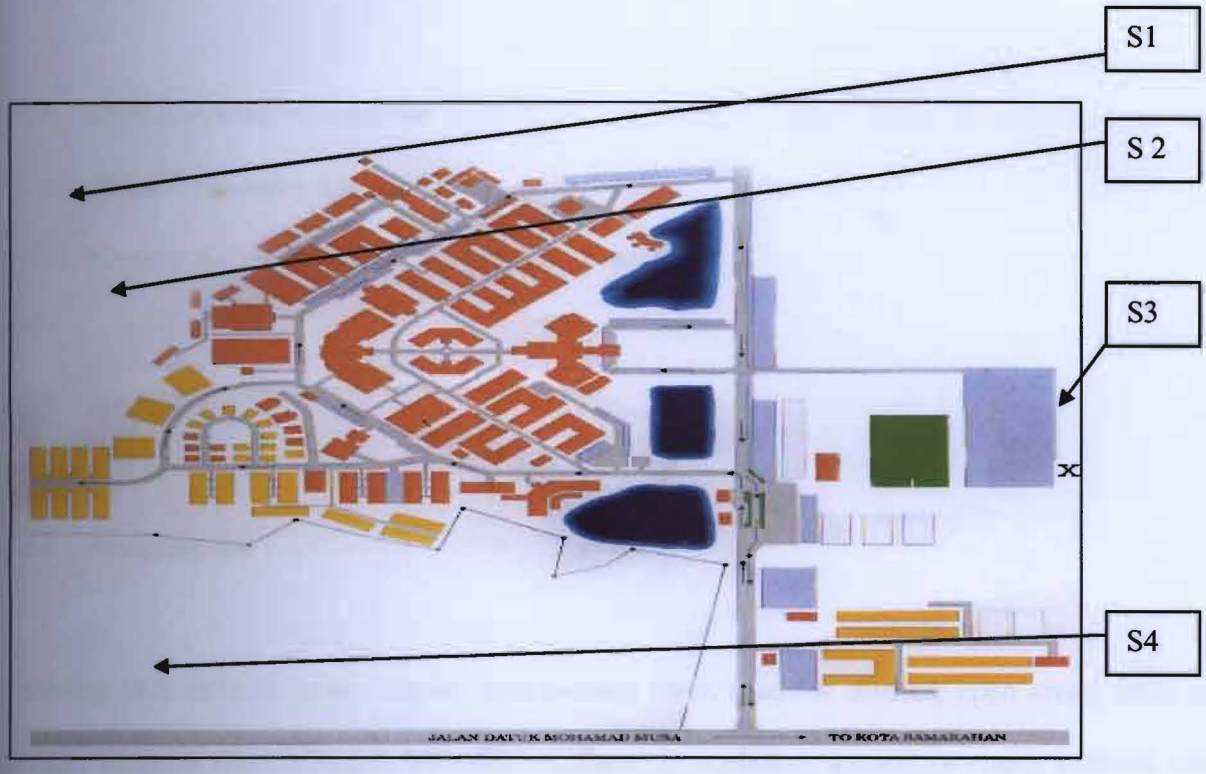
Brillouin's Index (HB) was used to analyse the dietary diversity for each species of anurans larvae in forested and open areas and the dietary breadth of the niche for the food ingested was calculated by Shannon-Weiner (H') (Krebs, 1999). For this study, cluster analysis was applied to the similarity matrix obtained by the SPSS version 11.0. The dietary overlap for the preys ingested among the anuran larvae species was measured using the Pianka's measure (Krebs, 1999).

3.0 Materials and methods

3.1 Study site

The study was conducted at the peat swamp forest adjacent to the temporary campus of Universiti Malaysia Sarawak (UNIMAS), in Kota Samarahan (Figure 1). It is situated at latitude 01° 27' 34.2" N and longitude 110° 27' 25.9" E. The elevation is 49 m above sea level while the relative humidity 75 RH on 31st August, 2006 on the evening. It is about 32 km from Sarawak's capital city, Kuching. This locality was logged about 50 years ago, and at present, secondary peat swamp forest dominates.

Tadpoles were collected at the selected sites above, and the sites were changed based on the number of specimens obtained. During the sampling period from August 2006 to April 2007, rainfall was constant for every month, except in February 2007 when heavy rainfall occurred, making field work impossible.



Legend; S: site

Figure 1: Location and selected sites at the Unimas campus for collecting tadpoles (Source: CALM UNIMAS).

3.2 Materials

1. Dip-net
2. Chemicals for fixing and preserving-4% formalin and 70% ethanol
3. 0.1% MS 222 (3-amino-benzoic acid ethyl ester)
4. Dissecting set
5. Measuring tape
6. Digital caliper
7. Digital camera (Nikon F 65, Fuji Velvia)
8. Stereoscopic microscope with camera

9. Swift compound microscope
10. Global Positioning System (GPS)
11. Plastic vials

3.3 Methods

3.3.1 Sampling site

Sampling sites included water stream, peat swamp, river, roadside ditches, open areas, drain and puddle. Tadpoles were collected with dip-net placed in a plastics aquaria or empty mineral water bottles. The tadpoles were captured either during the day or night. According to Leong (2005), anuran larvae were more readily visible and active at night.

Tadpoles collected were preserved on-site in 70% ethanol and some life individuals were taken back for photography. For identification, tadpoles were stored in 4% buffered formalin solution immediately to avoid any loss of prey ingested through active digestmatic breakdown.

3.3.2 Morphology of specimens

Tadpoles were anesthetized in 0.1% MS222 before photographs were taken and preserved for measurements and other data, which include total body length, snout-vent-length (SVL), body mass and developmental stages (refer Appendix 1). Total body length was measured by digital calipers from the snout to the tail tip.

Some tadpoles that could not be identified on site were taken back to the laboratory for identification. The tadpoles were identified using Inger (1986), Inger and Stuebing (2005), and Leong (2005) in developmental stages 30-38 as defined by Gosner (1960), (see Figure 2).

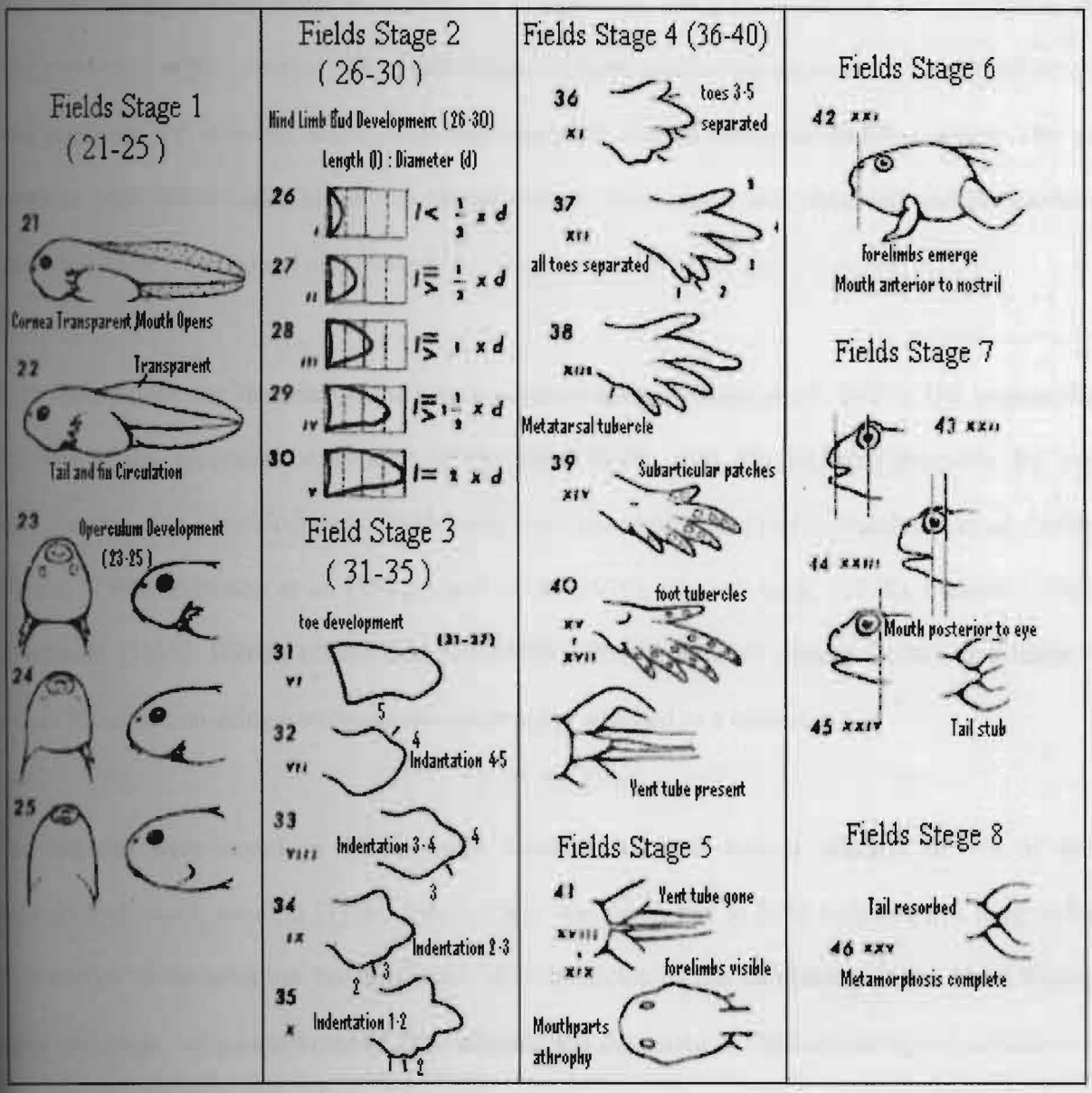


Figure 2: Developmental stages of anurans embryos and larvae (Gosner, 1960).

3.3.3 Analysis of gut contents of specimens

Rossa-Feres *et al.* (2004) observed that the manicotto glandulare of tadpoles was usually empty and that food content did not differ in quantity or composition along the intestine. The content of the first centimeter of the intestine of five individuals of each species was analyzed. The part of the gut was removed and their gut walls were removed with several drops of distilled water. The gut contents were spread and a cover slip placed over it. Each smear was observed and the contents identified under a compound microscope.

Each dietary item was identified to the lowest possible taxon (Schafer *et al.*, 2002). The unidentified contents of the specimens were kept in the small bottle with 4% buffered formalin for later identification. The identification of food items were based on Chu (1949), Hutabarat *et al.* (1986), Mizuno (1968), Patterson *et al.* (1992), Jahn *et al.* (1979), Prescott *et al.* (1978), Prescott (1982), Shamsudin (1991), Battish (1992) and Sze (1998). Photographs of dietary items were taken to ensure identification using a stereoscopic microscope attached to a camera.

The tadpoles were stored in 4% buffered formalin solution with a dilution of 1:9 of 40% formaldehyde stock solution (Tyler, 1963). Care was taken not to hold tadpoles too long before examination or preservation because some shed denticles in the laboratory. After identification, some specimens were transferred of 70% ethanol and deposited in the herpetological collection of Unimas museum. Data were analyzed based on observations both in the field and the laboratory. Refer to Appendix 3 for further details.

3.3.4 Data analysis

For dietary analysis, food items were identified and counted in the entire area covered by a cover slip with a grid calibrated on the slide. The frequencies of the prey ingested by the tadpoles were expressed in percentage. Data were analyzed using SPSS Version 11. Brillouin's Index (HB) and Shannon- Weiner Index (B) were calculated using the DIVERS program (Krebs, 1999), that has been adapted and modified for ease of data input and output (Laman, 2001). The index was used based on the frequency of occurrence of prey types and dominance. The formula used is

$$HB = (1/N) \log \left(N!/n_1!n_2!n_3! \right)$$

Where HB = Brillouin's Index

N = Total number of individuals in entire collection

n_1= Number of individuals belonging to Species 1

n_2= Number of individuals belonging to Species 2

Niche breadth of diet was estimated using the Shannon-Weiner Index (B) of diversity. The formula used is

$$H' = -\sum p_j \log p_j$$

where H' = Shannon- Weiner measure of niche breadth

p_j = Proportion of individuals found in or using resource j

$(j = 1, 2, 3...n)$

n = Total number of resource states

Dietary overlap between the seven anuran larvae species was calculated using a symmetrical measure; Pianka's modification of the McArthur-Levins measure (Krebs, 1999). The formula used is

$$O_{jk} = \frac{\sum p_{ij} p_{ik}}{\sqrt{\sum p_i^2{}_j p_i^2{}_k}}$$

where O_{jk} = Pianka's measure of dietary overlap of between species k on species j

p_{ij} = Proportion that resource i is of the total resource used by species j

p_{ik} = Proportion that resource i is the total resource used by species k

n = Total number of resource states

4.0 Results

4.1 Spectrum of food items

Tadpoles belonging to seven species from two families, Ranidae and Rhacophoridae, were studied. Four species were found in peat swamp forests- *Rana baramica, Limnonectes paramacrodon, R. erythraea* and *Polypedates otilophus*, while an adjacent area with freshwater swamp had three- *Fejervarya limnocharis, F. cancrivora* and *P. leucomystax*.

Tadpole diets consisted primarily of microalgae, although unidentified prey was also found. Other items recovered in intestinal samples include Nematoda and Copepoda. Microalgae belonging to 34 genera were identified. Diatoms (Bacillariophyricae) represented 14-28% of the diet of tadpoles of seven species recorded in the forested and open areas.

Table 1: Dates, stages of development and category/ microhabitats of tadpole collection from the open and forested areas in Unimas East Campus, Sarawak.

Species	Stage	Date	Habitat category/microhabitat
Rana baramica	30, 32, 34, 35	2/9/2006	Forest; open pool
Rana erythraea	31, 35, 36	11/9/2006	Forest; stream edge forest
Limnonectes paramacrodon	32, 34, 36, 38	11/9/2006	Forest; open pool
Fejervarya limnocharis	32, 34, 36	20/9/2006	Open; roadside puddle and ditch
Fejervarya cancrivora	31, 32, 36	13/10/2006	Open; roadside puddle
Polypedates leucomystax	30, 32, 34, 38	20/9/2006	Open; roadside puddle
Polypedates otilophus	32, 34, 36	12/12/2006	Forest; small stream

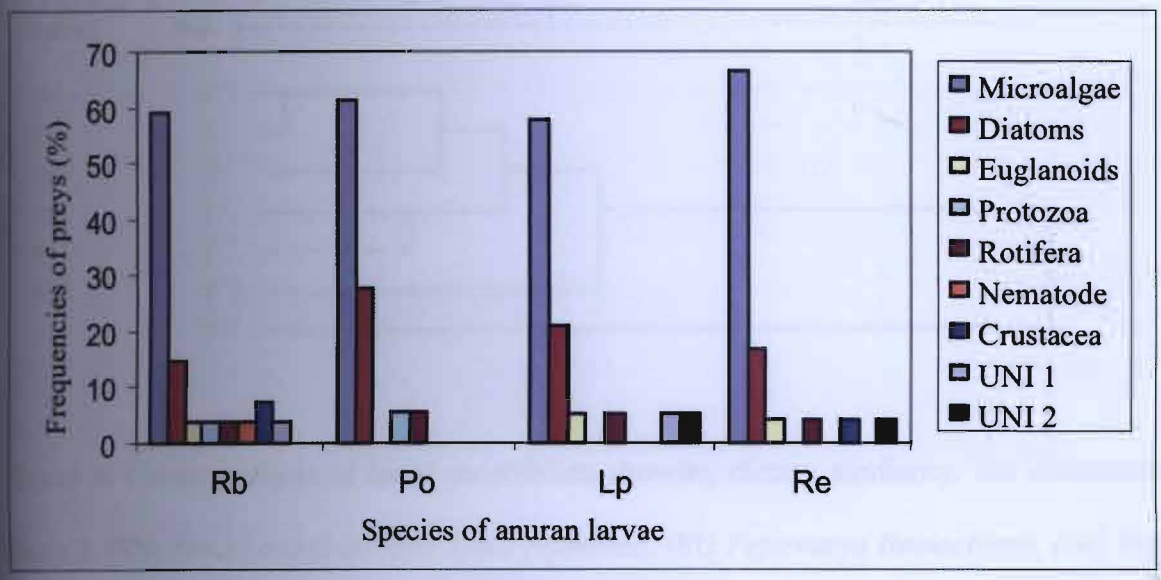
Table 2: Frequency distribution of food items of various sizes smears from the foreguts of tadpoles. (Rb) *Rana baramica*, (Re) *Rana erythraea*, (Fl) *Fejervarya limnocharis*, (Fc) *Fejervarya cancrivora*, (Pl) *Polypedates leucomystax*, (Lp) *Limnonectes paramacrodon*, and (Po) *Polypedates otilophus*. (UNI) unidentified item

Food items	Rb	Re	Fl	Fc	Lp	Pl	Po
Chlorophyta							
Carteria	+	-	-	-	-	-	-
Eurastrum	+	-	+	+	-	-	-
Rhizoclonium	+	-	+	+	-	+	-
Closterium	+	-	-	+	+	+	+
Spyrogyra	-	-	-	-	-	-	-
Micrasterias	+	+	-	-	-	-	-
Tetracytis	-	-	-	-	+	+	-
Ankistrodesmus	-	+	+	-	-	-	-
Chlamydomonas	-	+	-	-	-	-	-
Gleocystis	-	+	-	-	-	-	-
Pediastrum	-	+	+	+	-	-	+
Cosmarium	-	+	-	+	+	+	+
Hydroseria	-	+	-	-	-	-	-
Mougeotia	+	-	-	+	+	-	-
Netrium	+	+	-	-	+	-	+
Oodegonium	+	+	-	-	+	-	-
Microspora	-	-	+	-	-	-	+
Coleochaete	+	+	+	+	+	+	+
Tetraedron	-	-	+	+	-	-	-
Trentepohlia	-	-	-	+	-	-	-
Ulothrix	-	+	-	+	-	-	-
Notholca	+	-	+	-	+	-	-
Cyanophyta							
Anabaena	+	+	+	-	-	+	-
Anacystis	+	-	-	-	-	-	-
Chroococcus	-	+	+	+	+	+	-
Microcyctis	+	+	+	-	-	-	-
Oscillatoria	+	+	+	+	+	-	-
Gloecapsa	+	-	+	+	-	-	+
Nivolaria	-	+	-	+	-	-	-
Dactylococcopsis	-	-	+	+	-	-	+

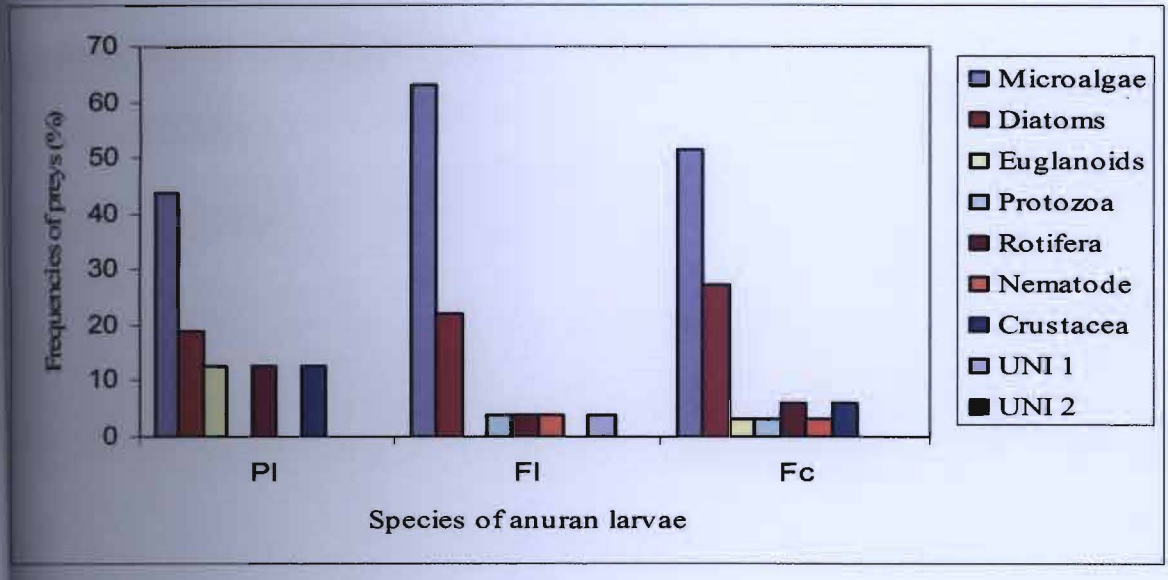
Plectonema	+	-	+	-	+	-	+
Gomphospaeria	-	-	+	-	-	-	+
Phormidium	-	-	-	+	-	-	+
Merismopedia	-	-	+	+	-	-	-
Diatoms (Chrysophyta)							
Flagilaria	+	+	-	+	-	-	+
Nhzchia	-	+	-	-	-	-	-
Navicula	-	+	-	+	-	-	+
Coconeis	-	-	+	-	-	+	-
Diatoma	+	+	+	+	+	-	-
Coscinodiscus	+	-	-	-	+	+	+
Pinnularia	-	-	-	+	+	+	-
Frustularia	-	-	+	-	-	-	-
Meridion	-	-	-	+	-	-	-
Cymbella	+	-	+	+	-	-	-
Eunotia	-	-	+	+	+	-	+
Epithemia	-	-	+	+	-	-	+
Nedium	-	-	-	+	-	-	-
Euglenophyta							
Phacus	+	+	-	+	+	-	-
Euglena	-	-	-	-	-	+	-
Eudorina	-	-	-	-	-	+	-
Rotifera							
Brachionus	+	-	+	-	-	-	-
Lepadella	-	-	-	+	-	-	-
Lecane	-	-	-	+	+	+	+
Lopocharis	-	-	-	+	-	-	-
Bosmina	-	+	-	-	-	+	-
Protozoa							
Paramoecium	+	-	-	-	-	-	-
Entamoeba	-	-	+	+	-	-	+
Crustacea (UNI)	+	+	-	-	-	+	-
Copepoda	+	-	-	+	-	+	-
Nematode	+	-	+	+	-	-	-
UNI 1	+	-	+	-	+	-	-
UNI 2	-	+	-	-	+	-	-
TOTAL PREY	**27**	**24**	**27**	**33**	**19**	**16**	**18**

Table 3: Categories of food items ingested and their percent frequencies (%) in the diet of tadpoles of seven species. (Rb) *Rana baramica*, (Re) *Rana erythraea*, (Fl) *Fejervarya limnocharis*, (Fc) *Fejervarya cancrivora*, (Pl) *Polypedates leucomystax*, (Lp) *Limnonectes paramacrodon*, and (Po) *Polypedates otilophus*. Five specimens of each species were examined. (UNI) unidentified item

	Rb	Re	Fl	Fc	Lp	Pl	Po
Microalgae	59.259	66.667	62.963	51.5152	57.895	43.75	61.111
Diatoms	14.815	16.667	22.2222	27.2727	21.053	18.75	27.778
Euglenoids	3.7037	4.1667	0	3.0303	5.2632	12.5	0
Protozoa	3.7037	0	3.7037	3.0303	0	0	5.5556
Rotifera	3.7037	4.1667	3.7037	6.06061	5.2632	12.5	5.5556
Nematode	3.7037	0	3.7037	3.0303	0	0	0
Crustacea	7.4074	4.1667	0	6.06061	0	12.5	0
UNI 1	3.7037	0	3.7037	0	5.2632	0	0
UNI 2	0	4.1667	0	0	5.2632	0	0



A



B

Figure 3: Percentage of food habits in intestinal sections tadpoles from **A (forested areas)** and **B** (open area) in the Unimas East Campus, Sarawak. (Rb) *Rana baramica*, (Re) *Rana erythraea*, (Fl) *Fejervarya limnocharis*, (Fc) *Fejervarya cancrivora,* (Pl) *Polypedates leucomystax,* (Lp) *Limnonectes paramacrodon*, and (Po) *Polypedates otilophus*. (UNI) unidentified item

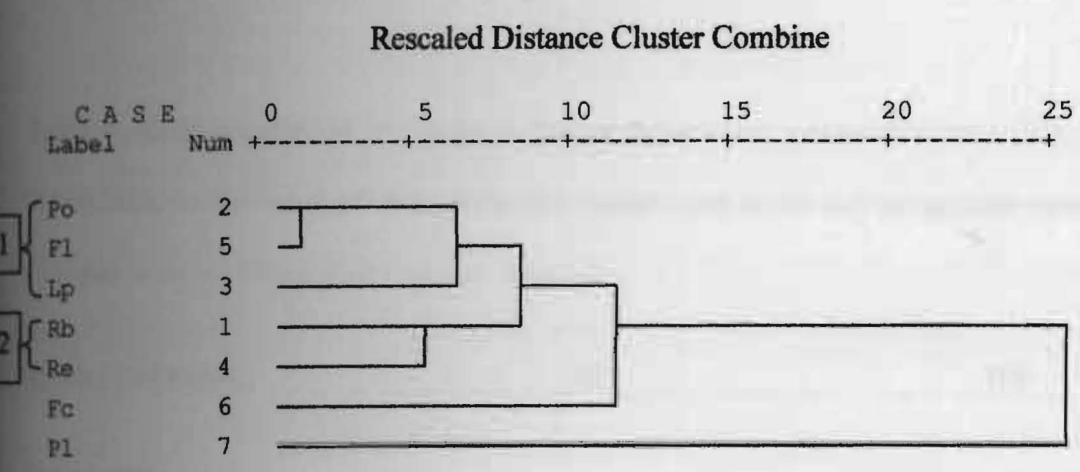


Figure 4: Cluster analysis of larval amphibians showing dietary similarity. For abbreviations see Table 3. (Rb) *Rana baramica*, (Re) *Rana erythraea*, (Fl) *Fejervarya limnocharis*, (Fc) *Fejervarya cancrivora*, (Pl) *Polypedates leucomystax*, (Lp) *Limnonectes paramacrodon*, and (Po) *Polypedates otilophus*.

Table 4: Niche breadth (H' = Shannon-Weiner Index) and dietary diversity (HB = Brillouin's Index) based on frequency of occurrence of resource types in the diet of tadpoles from the forested and open areas in Unimas East Campus, Sarawak.

Species and habitat	H'	HB
Forest area		
Rana baramica	4.755	3.450
Rana erythraea	4.585	3.293
Limnonectes paramacrodon	4.248	2.987
Polypedates otilophus	4.170	2.917
Open area		
Fejervarya cancrivora	5.044	3.718
Fejervarya limnocharis	4.755	3.450
Polypedates leucomystax	4.000	2.766

Table 5: Dietary overlap based on frequency of occurrence of resource types among the anuran larvae species from the forested and open area in Unimas East Campus, Sarawak. (Rb) *Rana baramica*, (Re) *Rana erythraea*, (Fl) *Fejervarya limnocharis*, (Fc) *Fejervarya cancrivora*, (Pl) *Polypedates leucomystax*, (Lp) *Limnonectes paramacrodon*, and (Po) *Polypedates otilophus*. For the abbreviations see Table 3.

Species	Rb	Re	Fl	Fc	Lp	Pl	Po
Rb	-	0.213	0.229	0.195	0.18	0.153	0.163
Re		-	0.389	0.389	0.358	0.37	0.339
Fl			-	0.437	0.414	0.418	0.366
Fc				-	0.424	0.435	0.403
Lp					-	1.394	0.918
Pl						-	0.885
Po							-

4.2 Dietary diversity and similarity

Tadpoles of five species- *Rana baramica, R. erythraea, Fejervarya limnocharis, F. cancrivora* and *Limnonectes paramacrodon* occur at the pond bottom or in benthic habitats, while *Polypedates otilophus* and *P. leucomystax* occur in the midwater columns. *R. baramica, P. otilophus* and *L. paramacrodon* were found in the forested areas, and ingested large amounts of algae. The members of each species pair were similar in terms of their respective diets (Figure 3), with only 4-6 items not shared (Table 2). *P. leucomystax* tadpoles showed the most assimilar diet, not sharing any category of resources with other anuran larvae (Figure 4). Within the congeneric pairs, *F. cancrivora* and *F. limnocharis*, the diet differed at least in terms of the most abundant item (Table 4). For the remaining species, 10-12 items were not shared (Table 2). Similarity analysis demonstrates two major species clusters with small distance values less than 8.0 (Figure 4): (1)

three species which ingested mainly algae and diatoms, and (2) two taxonomically related species (*R. baramica* and *R. erythraea*) which ingested mainly algae of the genus *Micrasterias*. Two species with different diets do not belong to either clusters: *F. cancrivora* and *P. leucomystax*.

Anuran species from the forested areas (*R. baramica, R. erythraea, L. paramacrodon* and *P. otilophus*) showed no difference in their diet composition. *R. baramica* fed on eight resource types and is thus a generalist in the forested areas, compared to *L. paramacrodon* and *R. erythraea* which are intermediate in dietary diversity, and *P. otilophus* is a dietary specialist. In the open area, *F. limnocharis* was an intermediate species. *F. cancrivora* tadpoles is a generalist, consuming seven resource types. *P. leucomystax* tadpoles are specialists of open areas, feeding on five resource types (see Figure 3).

The niche breadth and diversity of the food types ingested were high ($H' \geq 4.000$ and $HB > 2.5$, respectively) for most species (Table 4). Dietary overlap was high ($Ojk > 0.40$) between species. *R. baramica* tadpoles, which only fed on *Carteria* sp, *F. cancrivora* tadpoles which were predominantly mycophagous, and *P. leucomystax* tadpoles, which mainly consumed planktonic algae, were the only ones presenting low dietary diversity relative to other species (Table 4). The highest dietary diversity was observed in *F. cancrivora, R. baramica* and *F. limnocharis* and the highest dietary overlap occurred between *L. paramacrodon* and *P. leucomystax* (Table 5).

5.0 Discussions

5.1 Diet, microhabitat and feeding behavior

Information available on the diet of tadpoles is sparse, and field studies of tadpoles diet are rare relative to those on adults (Inger, 1986; Alford, 1999; Sinha *et al.*, 2001; Quammen and Durtsche, 2001; Altig, *et al.*, 2007). From what little is known, algae and detritus are the most abundant category food ingested, and they prefer algae with relatively high protein content (Kupferberg, 1997). In this study, some of the algae were found broken and without any organelles in the gut of tadpoles, but it is not known if the tadpoles digested these algae because they are not known to have cellulase for digesting plant materials (Hoff *et al.*, 1999; Rossa-Feres *et al.*, 2004). Euglenoids along with several species of Chlorophyceae and Baccilariophyceae were found undamaged in the intestinal contents of *Rana baramica*, *R. erythreae*, *Fejervarya cancrivora* and *Limnonectes paramacrodon* tadpoles. The detection of Copepoda and other soft-bodied animals such as Rotifera in the intestines is important in tadpoles and may be the real source of nutrient for tadpoles (Dutra and Callisto, 2005). As suggested by Hoff *et al.* (1999), the contribution of these small items to tadpole diets remains unstudied in nature, and part of the material that a tadpole ingests that is actually digested is not known.

Competition between *F. limnocharis* and *F. cancrivora* which were found in the same habitat was presumably avoided through ingestion of different food types, as reflected by differences in mouthparts (see Appendix 4). Wassersug (2001) commented that tadpoles of a majority of anuran species have anatomically complex mouth parts. Tadpole mouthpart and feeding mechanics are thus

constrained by the fact that mouth must be able to capture both food and air throughout the larval period. Biologists have long known that closely-related species are often phenotypically different where they co-occur (Pfennig, 2000).

Unidentified items found in *Rana baramica*, *Limnonectes paramarodon* and *Fejervarya limnocharis* gut are similar in shape to members of *Closterium* sp., but its identification was impossible because no recognizable structures were found. Leong (2005) suggested that both species were benthic larvae which consumed more microalgae. Unidentified items found in *R. erythraea* and *L. paramacrodon* also was unrecognizable, as the shape of items is similar to members of *Oocytis* sp. The data obtained suggest that the occurrence of food selection which results in the ingestion of different proportions of the food items available in the habitat rather than in different diet compositions. According to study done by Kupferberg (1997), tadpoles foraged selectively on the algae that promoted most rapid growth and development.

Observations on tadpole feeding and analysis of their mouthparts indicate that they tend to scrape or graze their food off substrates (see Appendix 4). Besides the external morphology, several researchers found a relationship between internal structure and ecology, linking anatomical features to specific ecological traits (Candioti, 2005). Feeding may be not so easily seen that it does not increase tadpole visibility, or perhaps tadpoles stop feeding as soon as the predator or competitor was introduced (Mokany and Shine, 2003).

Water is a dense and viscous medium, posing specific problems to predators who want to capture prey in a water column. Most invertebrates utilize totally different strategy such as particle or

suspension feeding because of the sizes and have to feed at extremely low number (Herrel and Aerts, 2004). The process of generating flow to capture prey is referred to as 'suction feeding'. Most of the anuran larvae engage in filter feeding which based on generation of steady flow water across a filter sieve which extracts particles from the surrounding water. In this system, particles are filtered out by size, shape and density rather than food value. *Rana erythraea* and *Polypedates otilophus* tadpoles which are found in stream areas differed in the number of prey types harvested. As suggested by Herrel and Aerts (2004), the rate of food accumulation is dependant on water flow.

The influence of microhabitat on the partitioning of food resources was demonstrated by similarity analysis which divided the tadpoles into two categories: those that mainly preferred algae of the genus *Coleochaete* and those that mainly ingested diatoms. The first group contains both taxonomically related species and species belonging to different family, all of them occurring on the bottom of the water except for *P. otilophus*. The second consisted of two taxonomically related species, *R. baramica* and *R. erythraea*, which occur at the midwater column and forest areas. Rossa-Feres *et al.* (2004) also detected two clusters in a community of twelve species in temporary pond in Brazil: tadpoles of the first cluster mainly feed diatoms as a consequence of occupying the same microhabitat. Diaz-Paniagua (1985) also got the same results where bottom tadpoles mainly ingested detritus and periphytic algae and midwater tadpoles which mainly ingested phanerogams or phytoplankton.

However, microhabitat partitioning alone does not fully explain two clusters, because *F. cancrivora* tadpoles although occurring in bottom, presented a different diet compared to the remaining tadpoles that occupied the same microhabitat. *F. cancrivora* tadpoles ingested Rotifera more

compare to other tadpoles, whereas *R. baramica* and *R. erythraea* tadpoles scrape surfaces for food, a fact which explains the only species feed on algae of *Micrasterias*- a species that occur principally in soft water or acid habitats such as peat swamp area (Prescott, 1982). Furthermore, *R. baramica, R. erythraea, Fejervarya limnocharis, F. cancrivora* and *Limnonectes paramacrodon* despite showing morphology associated with typical bottom suspension dwellers, were observed swimming near the surface upside down, especially at night. This behavior may explain the predominance of planktonic algae in their diets. *P. otilophus* and *P. leucomystax* tadpoles, despite being typical midwater larvae (Inger, 1986), consumed a diet that different from those of all other tadpoles. This is suggestive of higher extinction threat, due to its narrow diet. As suggested by Dutra and Callisto (2005), this may due to high resource availability in the environment and the feeding mechanism of the anuran larvae. These data showed that dietary partitioning is related not only to the activity of different microhabitats, but also the feeding behaviour of the tadpoles.

Dietary partitioning among anuran larvae is caused by differences in the ability of the various species to ingest the particles of varying sizes and types of position area they inhabit. In forested areas, anuran larvae in the analysis of dietary overlaps shows resource partitioning with low overlap overall at the community level in both areas. Not surprising, overlaps are much higher for the unspecialized feeding associations.

The importance of dietary partitioning in the organization in the tadpole communities is still unclear (Altig *et al.*, 2007). Heyer (1974) suggested that space and time were much more important than dietary partitioning, whereas Inger (1986) observed that the different feeding modes of tadpoles are related to microhabitat distribution and some of the differences in diet composition. In the present

study, as suggested by Rossa-Feres *et al.* (2004), the low feeding overlap among the species shows that dietary partitioning was a factor that contributed to tadpole segregation, especially those of different genera, which occupied different habitats and presented different feeding behaviour.

5.2 Similarity of diets of related species

Among tadpole species from the forested areas (*Rana baramica, Limnonectes paramacrodon* and *Polypedates otilophus*), the similarity of larval diets among these species showed related pair tended to present greater niche breadth. Dietary diversity in food type was higher among *Fejervarya cancrivora, F. limnocharis* and *R. baramica*. The similarity of larval diets among the species is apparent from the analysis of gut contents. In contrast, the niche breadth of *R. baramica* and *F. limnocharis* was similar in the variety of items. Dietary overlap in types of preys ingested was higher among P. *leucomystax* and *L. paramacrodon*. This suggests that dietary overlap may be greater among more generalist species.

n the two pairs of taxonomically related species, niche breadth was high, except for *P. eucomystax*. However some non-congeneric species (e.g., *F. limnocharis* and *R. baramica*) showed qual or same niche breadth. These data show that the similarity of the tadpole diet cannot be xplained only by taxonomic proximity (see Figure 4). As suggested by Rossa-Feres *et al.* (2004), is does not mean that taxonomic proximity, a historical factor, is important. Rather, feeding ehavior and microhabitat use may also influence the pattern of food resource. These data display at organization of two communities is complex and results from the relations of numerous factors.

6.0 Conclusions

The results of this study show how dietary resources partitioning can influence anuran larvae communities. There are significant differences between food resources of co-occurring species and the dietary diversity of tadpoles between forested and open areas. This is due to partitioning of available resources by syntopic species, which may utilize different kinds and sizes of food or forage in different areas. Each species exploits a portion of the resources available, for whatever reasons, relative to other species. In addition, the quantitative differences among food types, such as the amount of different algae, can affect size and types of species. The oral disk or mouthpart also influences the types of food consumed.

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Appendix 1

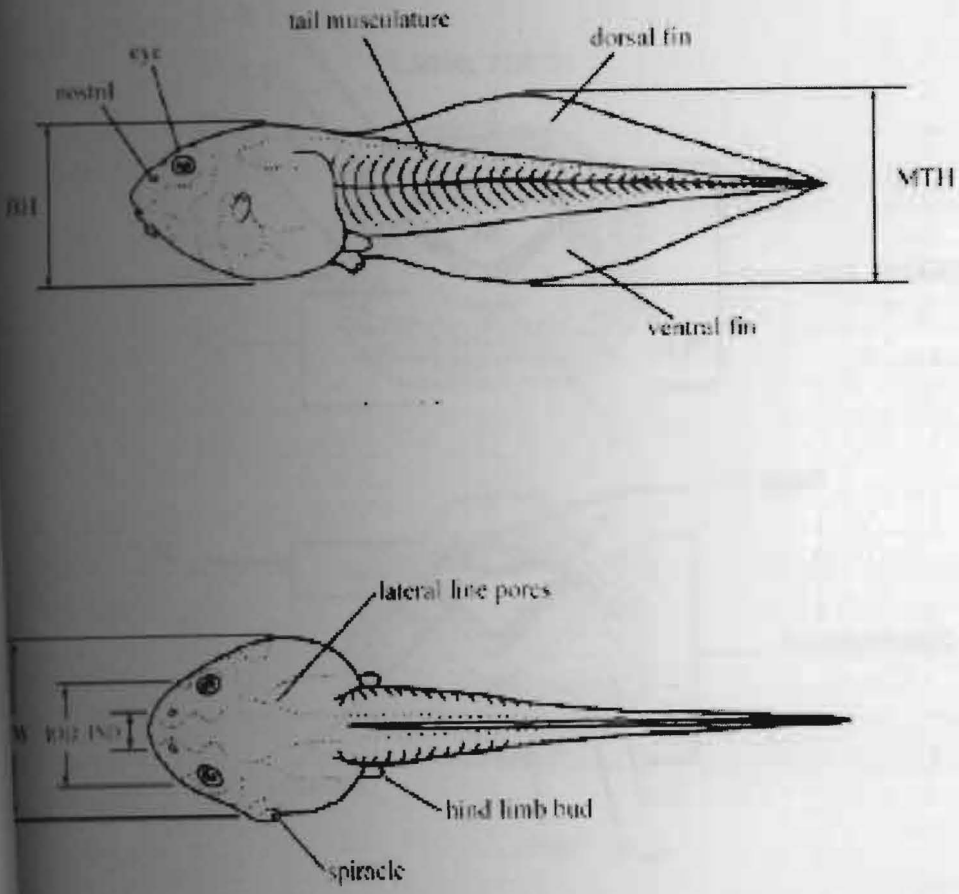


Figure 5: Schematic diagram of a generalized anuran larva (lateral, dorsal and ventral aspects), illustrating the essential morphometric parameters: BL (Body Length), TAL (Tail Length), TL (Total Length), MTH (Maximum Tail Height), IOD (Inter-orbital Distance), IND (Inter-narial Distance), BW (Body Width), BH (Body Height), Sn-Sp (Snout-spiracular distance) and ODW (Oral Disc Width). Source: Leong, (2005).

Appendix 2

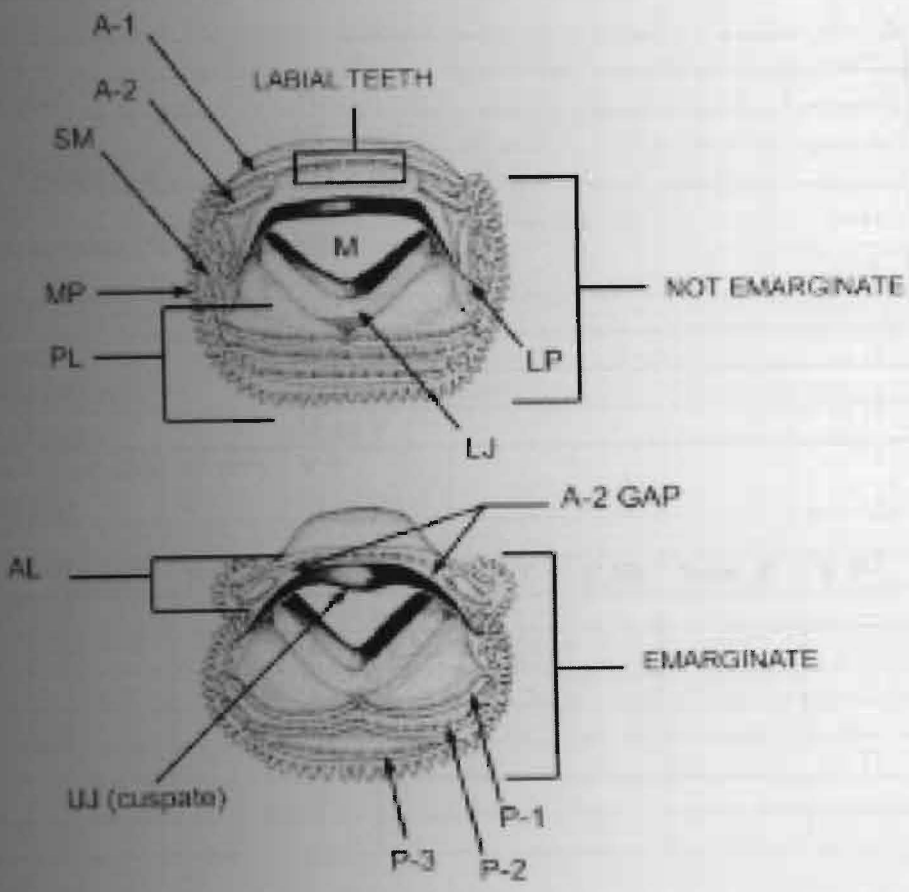


Figure 6: Generalised tadpole mouth-part morphology (Source: Gregoire, 2005).

Appendix 3

Data sheet used analyze for observations in the field and laboratory.

	Data	
1	Serial number	SL
2	Species	SP
3	Locality (including GPS)	LOC
4	Date/ Time	D / T
5	Habitat description (% canopy cover)	HD
6	SVL (mm)	SVL
7	Weight (gm)	WT
8	Prey ID (to Order)	P ID
9	Number of prey	Num. P
10	Volumetric estimation of prey categories (%)	V P

	SL	SP	LOC	D/T	HD	SVL	WT	P ID	Num. P	V P
1										
2										
3										
4										
5										
6										
7										

Appendix 4

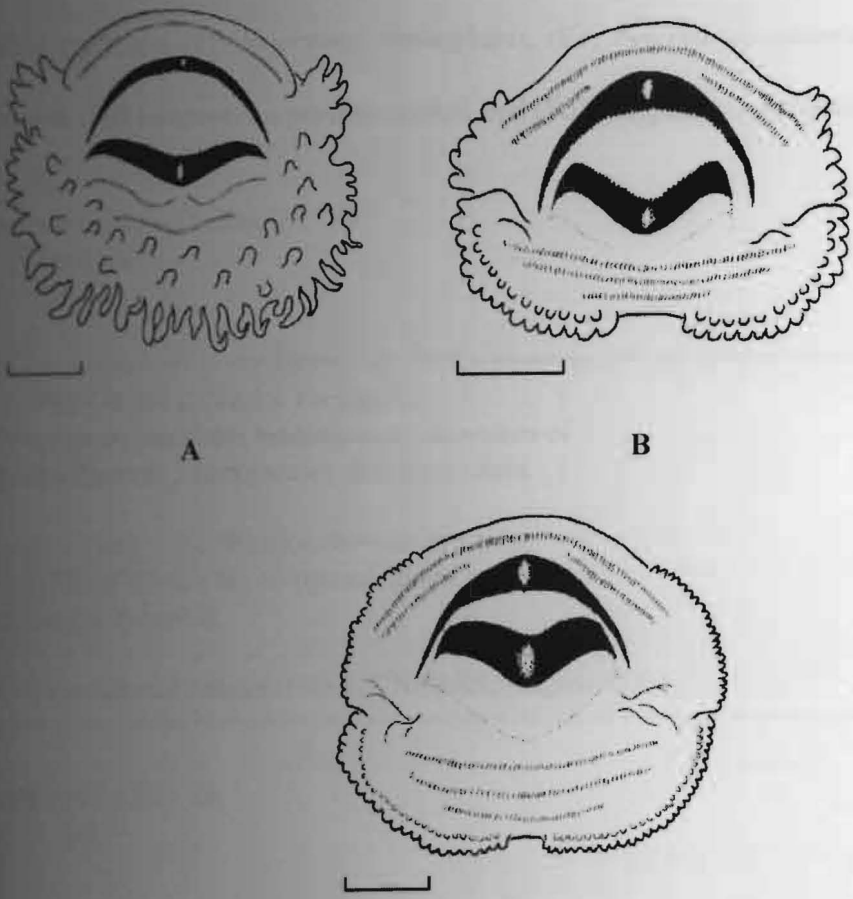


Figure 7: Comparisons of oral discs in larval *Rana erythraea* (A), *Fejervarya limnocharis* (B) and *F. cancrivora* (C). Note shared character of elongated marginal papillae in all species. Scale bars = 1 mm. Illustrated from larval specimen (ZRC.1.3381-3382, ZRC.1.3374 & ZRC.1.3377. respectively, all from Singapore, by Leong (2005).

Appendix 5

Divers output for the Shannon- Weiner Index (H) and Brillouin's Index (HB). (Rb) *Rana baramica*, (Re) *Rana erythraea*, (Fl) *Fejervarya limnocharis*, (Fc) *Fejervarya cancrivora*, (Pl) *Polypedates leucomystax*, (Lp) *Limnonectus paramacrodon*, and (Po) *Polypedates otilophus*.

```
Random number seed (1-30000)? 7896
Name of input file?
Rb.txt

================================================================
|        PROGRAM DIVERS Version 1.2                            |
|  This program calculates heterogeneity measures of           |
|   species diversity, from species abundance data.            |
|                                                              |
|  Simpson's index, the Shannon-Weiner function,               |
|  and Brillouin's index are computed, along with              |
|  estimates of evenness.                                      |
|                                                              |
|Modified by Charlie Laman (FRST, UNIMAS, August, 2001)        |
================================================================

 PROBLEM LABEL IS:
 ** Preys in Rb

 ABUNDANCE DATA, ONE SPECIES PER LINE, LAST DATA, INPUT
   AS 0.0 OR END-OF-FILE. (Maximum is 200 species)

 RAW DATA:
 SPECIES NO.   NO.OF INDIVIDUALS   PROPORTION OR SAMPLE
================================================================
     1            1.                0.037
     2            1.                0.037
     3            1.                0.037
     4            1.                0.037
     5            1.                0.037
     6            1.                0.037
     7            1.                0.037
     8            1.                0.037
     9            1.                0.037
```

10	1.	0.037
11	1.	0.037
12	1.	0.037
13	1.	0.037
14	1.	0.037
15	1.	0.037
16	1.	0.037
17	1.	0.037
18	1.	0.037
19	1.	0.037
20	1.	0.037
21	1.	0.037
22	1.	0.037
23	1.	0.037
24	1.	0.037
25	1.	0.037
26	1.	0.037
27	1.	0.037

.....ETC. UP TO 200 SPECIES
TOTAL NO.OF INDIVIDUALS = 27.

* SIMPSON DIVERSITY INDEX FOR INFINITE POPULATION (1-D) = 0.963
RECIPROCAL OF SIMPSON DIVERSITY INDEX FOR INFINITE POPULATION (1/D) = 27.000
SIMPSON DIVERSITY INDEX FOR FINITE POPULATION (1-Dhat) = 1.000

* SHANNON-WEINER DIVERSITY = 4.755 BITS PER INDIVIDUAL
NUMBER OF EQUALLY COMMON SPECIES, N(i) = 27.000

* BRILLOUIN'S DIVERSITY (H) = 3.450 BITS PER INDIVIDUAL.

MAXIMUM POSSIBLE DIVERSITY :
==========

SIMPSON (1-D) = 1.000 EVENNESS = 0.000

SHANNON-WIENER = 4.755 (EVENNESS = 1.000) (H/HMAX)

Random number seed (1-30000)? 9098
Name of input file?
Re.txt

```
==========================================================
|        PROGRAM DIVERS Version 1.2                      |
|  This program calculates heterogeneity measures of     |
|   species diversity, from species abundance data.      |
|                                                        |
|  Simpson's index, the Shannon-Weiner function,         |
|  and Brillouin's index are computed, along with        |
|  estimates of evenness.                                |
|                                                        |
|Modified by Charlie Laman (FRST, UNIMAS, August, 2001)  |
==========================================================
```

PROBLEM LABEL IS:
** preys in Re

ABUNDANCE DATA, ONE SPECIES PER LINE, LAST DATA, INPUT AS 0.0 OR END-OF-FILE. (Maximum is 200 species)

RAW DATA:

SPECIES NO.	NO.OF INDIVIDUALS	PROPORTION OR SAMPLE
1	1.	0.042
2	1.	0.042
3	1.	0.042
4	1.	0.042
5	1.	0.042
6	1.	0.042
7	1.	0.042
8	1.	0.042
9	1.	0.042
10	1.	0.042
11	1.	0.042
12	1.	0.042
13	1.	0.042
14	1.	0.042
15	1.	0.042
16	1.	0.042
17	1.	0.042
18	1.	0.042
19	1.	0.042
20	1.	0.042

```
    21          1.          0.042
    22          1.          0.042
    23          1.          0.042
    24          1.          0.042

     .....ETC. UP TO  200   SPECIES
0     TOTAL NO.OF INDIVIDUALS =     24.


0 * SIMPSON DIVERSITY INDEX FOR INFINITE POPULATION (1-D) =   0.958
   RECIPROCAL OF SIMPSON DIVERSITY INDEX FOR INFINITE
   POPULATION (1/D)                          = 24.000
   SIMPSON DIVERSITY INDEX FOR FINITE POPULATION (1-Dhat) =  1.000


  * SHANNON-WEINER DIVERSITY =  4.585     BITS PER INDIVIDUAL
   NUMBER OF EQUALLY COMMON SPECIES, N(i) =  24.000


0 * BRILLOUIN'S DIVERSITY (H) =  3.293 BITS PER INDIVIDUAL.


0  MAXIMUM POSSIBLE DIVERSITY :
   ==========================

      SIMPSON (1-D)  =   1.000    EVENNESS =  0.000

      SHANNON-WEINER =  4.585   (EVENNESS =   1.000) (H/HMAX)


Random number seed (1-30000)? 7898
Name of input file?
Fl.txt

============================================================
|         PROGRAM DIVERS Version 1.2                       |
|  This program calculates heterogeneity measures of       |
|   species diversity, from species abundance data.        |
|                                                          |
|  Simpson's index, the Shannon-Weiner function,           |
|  and Brillouin's index are computed, along with          |
|  estimates of evenness.                                  |
|                                                          |
| Modified by Charlie Laman (FRST, UNIMAS, August, 2001)   |
============================================================
 PROBLEM LABEL IS:
```

** preys in Fl

ABUNDANCE DATA, ONE SPECIES PER LINE, LAST DATA, INPUT
AS 0.0 OR END-OF-FILE. (Maximum is 200 species)

RAW DATA:

SPECIES NO.	NO.OF INDIVIDUALS	PROPORTION OR SAMPLE
1	1.	0.037
2	1.	0.037
3	1.	0.037
4	1.	0.037
5	1.	0.037
6	1.	0.037
7	1.	0.037
8	1.	0.037
9	1.	0.037
10	1.	0.037
11	1.	0.037
12	1.	0.037
13	1.	0.037
14	1.	0.037
15	1.	0.037
16	1.	0.037
17	1.	0.037
18	1.	0.037
19	1.	0.037
20	1.	0.037
21	1.	0.037
22	1.	0.037
23	1.	0.037
24	1.	0.037
25	1.	0.037
26	1.	0.037
27	1.	0.037

.....ETC. UP TO 200 SPECIES

0 TOTAL NO.OF INDIVIDUALS = 27.

0 * SIMPSON DIVERSITY INDEX FOR INFINITE POPULATION (1-D) = 0.963
RECIPROCAL OF SIMPSON DIVERSITY INDEX FOR INFINITE
POPULATION (1/D) = 27.000
SIMPSON DIVERSITY INDEX FOR FINITE POPULATION (1-Dhat) = 1.000
* SHANNON-WEINER DIVERSITY = 4.755 BITS PER INDIVIDUAL

NUMBER OF EQUALLY COMMON SPECIES, N(i) = 27.000

0 * BRILLOUIN'S DIVERSITY (H) = 3.450 BITS PER INDIVIDUAL.

0 MAXIMUM POSSIBLE DIVERSITY :

SIMPSON (1-D) = 1.000 EVENNESS = 0.000

SHANNON-WEINER = 4.755 (EVENNESS = 1.000) (H/HMAX)

Random number seed (1-30000)? 7898
Name of input file?
Fc.txt

```
|          PROGRAM DIVERS Version 1.2          |
|  This program calculates heterogeneity measures of |
|   species diversity, from species abundance data.  |
|                                                    |
|  Simpson's index, the Shannon-Weiner function,     |
|  and Brillouin's index are computed, along with    |
|  estimates of evenness.                            |
|                                                    |
| Modified by Charlie Laman (FRST, UNIMAS, August, 2001) |
```

PROBLEM LABEL IS:
** preys in fc

ABUNDANCE DATA, ONE SPECIES PER LINE, LAST DATA, INPUT AS 0.0 OR END-OF-FILE. (Maximum is 200 species)

RAW DATA:

SPECIES NO.	NO.OF INDIVIDUALS	PROPORTION OR SAMPLE
1	1.	0.030
2	1.	0.030
3	1.	0.030
4	1.	0.030
5	1.	0.030
6	1.	0.030
7	1.	0.030

8	1.	0.030
9	1.	0.030
10	1.	0.030
11	1.	0.030
12	1.	0.030
13	1.	0.030
14	1.	0.030
15	1.	0.030
16	1.	0.030
17	1.	0.030
18	1.	0.030
19	1.	0.030
20	1.	0.030
21	1.	0.030
22	1.	0.030
23	1.	0.030
24	1.	0.030
25	1.	0.030
26	1.	0.030
27	1.	0.030
28	1.	0.030
29	1.	0.030
30	1.	0.030
31	1.	0.030
32	1.	0.030
33	1.	0.030

.....ETC. UP TO 200 SPECIES

O TOTAL NO.OF INDIVIDUALS = 33.

O * SIMPSON DIVERSITY INDEX FOR INFINITE POPULATION (1-D) = 0.970
RECIPROCAL OF SIMPSON DIVERSITY INDEX FOR INFINITE
POPULATION (1/D) = 33.000
SIMPSON DIVERSITY INDEX FOR FINITE POPULATION (1-Dhat) = 1.000

* SHANNON-WEINER DIVERSITY = 5.044 BITS PER INDIVIDUAL
NUMBER OF EQUALLY COMMON SPECIES, N(i) = 33.000
O * BRILLOUIN'S DIVERSITY (H) = 3.718 BITS PER INDIVIDUAL.
O MAXIMUM POSSIBLE DIVERSITY :
==========

SIMPSON (1-D) = 1.000 EVENNESS = 0.000

SHANNON-WEINER = 5.044 (EVENNESS = 1.000) (H/HMAX)

Random number seed (1-30000)? 10002
Name of input file?
Lp.txt

```
==========================================================
|        PROGRAM DIVERS Version 1.2                      |
|  This program calculates heterogeneity measures of     |
|  species diversity, from species abundance data.       |
|                                                        |
|  Simpson's index, the Shannon-Weiner function,         |
|  and Brillouin's index are computed, along with        |
|  estimates of evenness.                                |
|                                                        |
| Modified by Charlie Laman (FRST, UNIMAS, August, 2001) |
==========================================================
```

PROBLEM LABEL IS:
** preys in Lp

ABUNDANCE DATA, ONE SPECIES PER LINE, LAST DATA, INPUT AS 0.0 OR END-OF-FILE. (Maximum is 200 species)

RAW DATA:

SPECIES NO.	NO.OF INDIVIDUALS	PROPORTION OR SAMPLE
1	1.	0.053
2	1.	0.053
3	1.	0.053
4	1.	0.053
5	1.	0.053
6	1.	0.053
7	1.	0.053
8	1.	0.053
9	1.	0.053
10	1.	0.053
11	1.	0.053
12	1.	0.053
13	1.	0.053
14	1.	0.053
15	1.	0.053
16	1.	0.053
17	1.	0.053
18	1.	0.053
19	1.	0.053

```
     .....ETC. UP TO  200   SPECIES
0      TOTAL NO.OF INDIVIDUALS =     19.


0  * SIMPSON DIVERSITY INDEX FOR INFINITE POPULATION (1-D) =   0.947
    RECIPROCAL OF SIMPSON DIVERSITY INDEX FOR INFINITE
    POPULATION (1/D)                          =  19.000
    SIMPSON DIVERSITY INDEX FOR FINITE POPULATION (1-Dhat) =   1.000


   * SHANNON-WEINER DIVERSITY =  4.248     BITS PER INDIVIDUAL
    NUMBER OF EQUALLY COMMON SPECIES, N(i) =  19.000


0  * BRILLOUIN'S DIVERSITY (H) =  2.987 BITS PER INDIVIDUAL.


0   MAXIMUM POSSIBLE DIVERSITY :
    ============================

       SIMPSON (1-D) =   1.000    EVENNESS =   0.000

       SHANNON-WEINER =   4.248   (EVENNESS =   1.000) (H/HMAX)


Random number seed (1-30000)? 9088
Name of input file?
Pl.txt

============================================================
|          PROGRAM DIVERS Version 1.2                      |
|   This program calculates heterogeneity measures of     |
|    species diversity, from species abundance data.       |
|                                                          |
|   Simpson's index, the Shannon-Weiner function,          |
|   and Brillouin's index are computed, along with         |
|   estimates of evenness.                                 |
|                                                          |
| Modified by Charlie Laman (FRST, UNIMAS, August, 2001)   |
============================================================

  PROBLEM LABEL IS:
  ** preys in Pl


  ABUNDANCE DATA, ONE SPECIES PER LINE, LAST DATA, INPUT
```

AS 0.0 OR END-OF-FILE. (Maximum is 200 species)

RAW DATA:

SPECIES NO.	NO.OF INDIVIDUALS	PROPORTION OR SAMPLE
1	1.	0.063
2	1.	0.063
3	1.	0.063
4	1.	0.063
5	1.	0.063
6	1.	0.063
7	1.	0.063
8	1.	0.063
9	1.	0.063
10	1.	0.063
11	1.	0.063
12	1.	0.063
13	1.	0.063
14	1.	0.063
15	1.	0.063
16	1.	0.063

.....ETC. UP TO 200 SPECIES

O TOTAL NO.OF INDIVIDUALS = 16.

O * SIMPSON DIVERSITY INDEX FOR INFINITE POPULATION (1-D) = 0.938
RECIPROCAL OF SIMPSON DIVERSITY INDEX FOR INFINITE POPULATION (1/D) = 16.000
SIMPSON DIVERSITY INDEX FOR FINITE POPULATION (1-Dhat) = 1.000

* SHANNON-WEINER DIVERSITY = 4.000 BITS PER INDIVIDUAL
NUMBER OF EQUALLY COMMON SPECIES, N(i) = 16.000
O * BRILLOUIN'S DIVERSITY (H) = 2.766 BITS PER INDIVIDUAL.

O MAXIMUM POSSIBLE DIVERSITY :

SIMPSON (1-D) = 1.000 EVENNESS = 0.000

SHANNON-WEINER = 4.000 (EVENNESS = 1.000) (H/HMAX)

Random number seed (1-30000)? 9990
Name of input file?
Po.txt

```
==========================================================
|        PROGRAM DIVERS Version 1.2                      |
|  This program calculates heterogeneity measures of     |
|   species diversity, from species abundance data.      |
|                                                        |
|  Simpson's index, the Shannon-Weiner function,         |
|  and Brillouin's index are computed, along with        |
|  estimates of evenness.                                |
|                                                        |
| Modified by Charlie Laman (FRST, UNIMAS, August, 2001) |
==========================================================
```

PROBLEM LABEL IS:
** preys in Po

ABUNDANCE DATA, ONE SPECIES PER LINE, LAST DATA, INPUT AS 0.0 OR END-OF-FILE. (Maximum is 200 species)

RAW DATA:

SPECIES NO.	NO.OF INDIVIDUALS	PROPORTION OR SAMPLE
1	1.	0.056
2	1.	0.056
3	1.	0.056
4	1.	0.056
5	1.	0.056
6	1.	0.056
7	1.	0.056
8	1.	0.056
9	1.	0.056
10	1.	0.056
11	1.	0.056
12	1.	0.056
13	1.	0.056
14	1.	0.056
15	1.	0.056
16	1.	0.056
17	1.	0.056
18	1.	0.056

.....ETC. UP TO 200 SPECIES

O TOTAL NO.OF INDIVIDUALS = 18.

O * SIMPSON DIVERSITY INDEX FOR INFINITE POPULATION (1-D) = 0.944
RECIPROCAL OF SIMPSON DIVERSITY INDEX FOR INFINITE POPULATION (1/D) = 18.000
SIMPSON DIVERSITY INDEX FOR FINITE POPULATION (1-Dhat) = 1.000

* SHANNON-WEINER DIVERSITY = 4.170 BITS PER INDIVIDUAL
NUMBER OF EQUALLY COMMON SPECIES, N(i) = 18.000

O * BRILLOUIN'S DIVERSITY (H) = 2.917 BITS PER INDIVIDUAL.

O MAXIMUM POSSIBLE DIVERSITY :
==========

SIMPSON (1-D) = 1.000 EVENNESS = 0.000

SHANNON-WEINER = 4.170 (EVENNESS = 1.000) (H/HMAX)

Appendix 6

Data output for the cluster analysis

Case Processing Summary[a,b]

Cases					
Valid		Missing		Total	
N	Percent	N	Percent	N	Percent
7	41.2	10	58.8	17	100.0

a. Euclidean Distance used

b. Average Linkage (Between Groups)

Average Linkage (Between Groups)

Agglomeration Schedule

Stage	Cluster Combined		Coefficients	Stage Cluster First Appears		Next Stage
	Cluster 1	Cluster 2		Cluster 1	Cluster 2	
1	2	5	8.283	0	0	3
2	1	4	11.302	0	0	4
3	2	3	11.869	1	0	4
4	1	2	13.350	2	3	5
5	1	6	15.277	4	0	6
6	1	7	24.419	5	0	0

Vertical Icicle

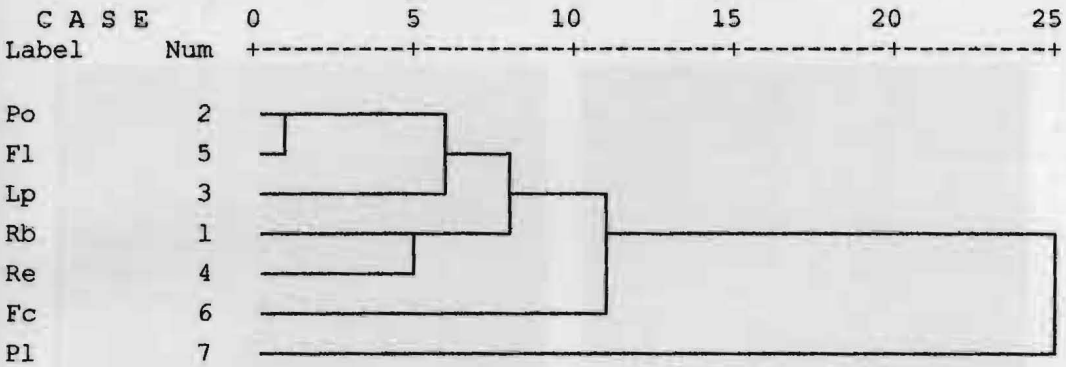
Number of clusters	Case												
	7:Pl		6:Fc		3:Lp		5:Fl		2:Po		4:Re		1:Rb
1	X	X	X	X	X	X	X	X	X	X	X	X	X
2	X		X	X	X	X	X	X	X	X	X	X	X
3	X		X		X	X	X	X	X	X	X	X	X
4	X		X		X	X	X	X	X		X	X	X
5	X		X		X		X	X	X		X	X	X
6	X		X		X		X	X	X		X		X

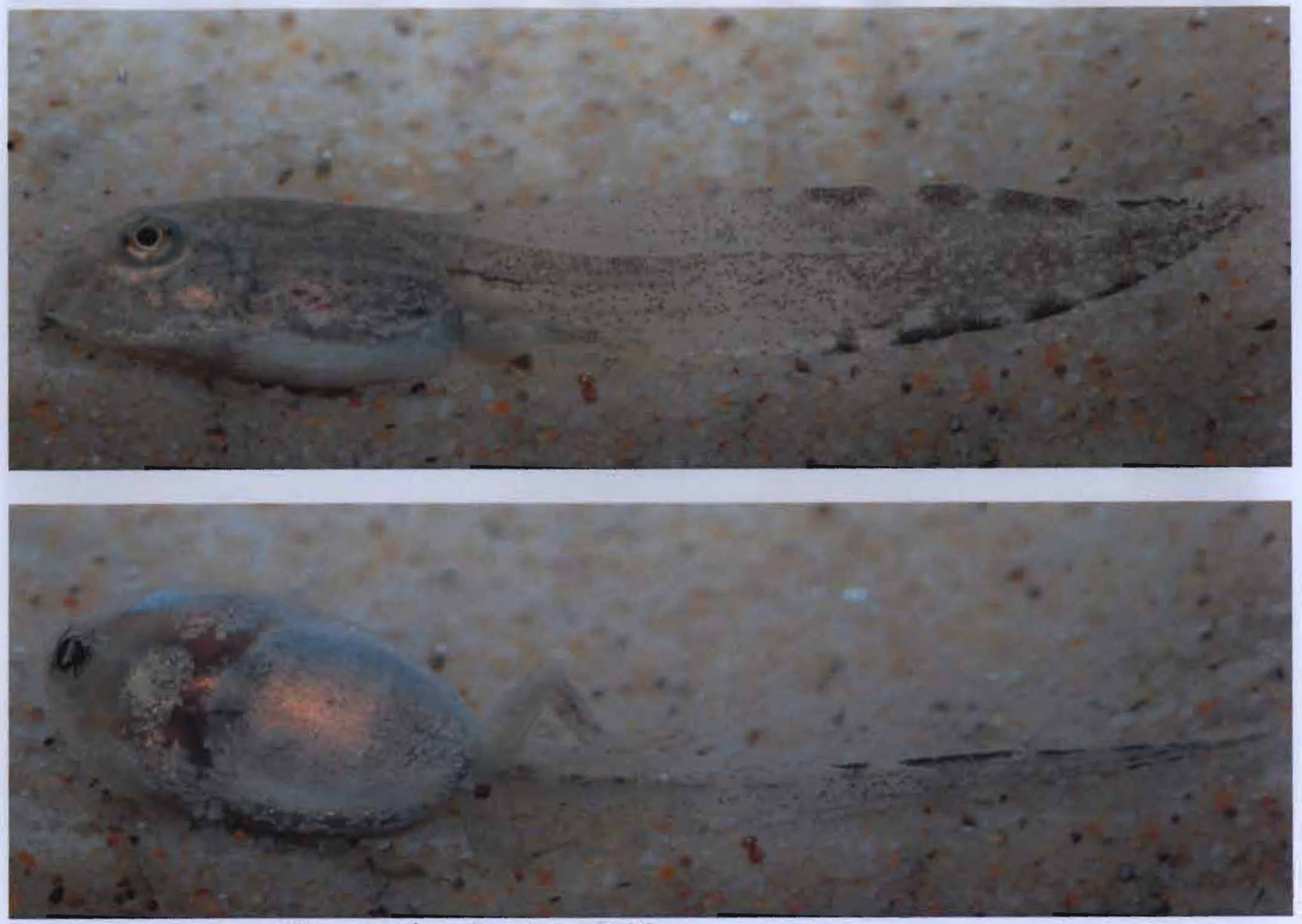
Dendrogram

******HIERARCHICAL CLUSTER ANALYSIS******

Dendrogram using Average Linkage (Between Groups)

Rescaled Distance Cluster Combine





Fejervarya cancrivora (Stage 38, from Borneo, SZ036).

Rana baramica (Stage 26, from Borneo, SZ037).

Figure 8: Larvae of *Fejervarya cancrivora* and *Rana baramica*.